



Standard Test Method for Bond Strength of Electrical Insulating Varnishes by the Helical Coil Test¹

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers determination of the bond strength of an electrical insulating varnish when applied to a helical coil. The helical coil can be made from bare aluminum or copper wire or from film or fiber-insulated magnet wire. Helical coils made from bare aluminum or bare copper wire will yield values of bond strength for the varnish when applied to bare metal conductors. The use of film or fiber-insulated magnet wire will show values for that particular combination of insulation and varnish.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See Section 7.

2. Referenced Documents

2.1 ASTM Standards:

D 115 Test Methods for Testing Solvent Containing Varnishes Used for Electrical Insulation²

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing³

3. Terminology

3.1 Definitions:

3.1.1 *bond strength*—a measure of the force required to separate surfaces which have been bonded together.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *event time*—the time between initial application of a physical or electrical stress and failure of the specimen under test.

3.2.2 *response time*—the time required for an indicating or

recording device to react to change in stress on a specimen under test.

4. Summary of Test Method

4.1 Flexural strength tests are made on varnish-treated helical coils to determine the force required to break the coil under specified conditions.

5. Significance and Use

5.1 Values obtained by flexural tests can provide information with regard to the bond strength of the particular varnish, in combination with a particular wire, when measured under conditions described in this test method.

6. Apparatus

6.1 *Tensile Testing Machine*—An adjustable-speed drive and a suitable instrument for measuring force should be used in breaking the specimen. This may be in the form of one of the generally available tensile testing machines, or may be simply an accurate spring gage and a separate adjustable-speed drive.⁴ To cover the range of load strength values which are commonly encountered it is recommended that a multirange tester be used.

6.1.1 It has been found that gages rated 5, 25, 150, and 500 N or (1, 5, 30, and 100 lbf) are adequate to cover the range of varnishes.

6.2 *Test Fixture*—The test fixture shall consist essentially of two rollers, attached to a common frame, to be pulled in one direction, and a 90° V-block to be pulled in the opposite direction. There shall be no friction contact which will affect this movement. The general shape and the relative position of these parts is shown in Fig. 1. The rollers shall have a diameter of 9.5 mm (0.375 in.) at the center and shall be parallel having a center-to-center distance of 44.5 mm (1.75 in.). The 90° V-block shall have a radius at the apex of 0.8 mm (0.03 in.).

6.3 *Test Fixture Enclosure*—For tests at other than room temperature, an insulated heat-resistant enclosure, designed to fit around the test fixture and into the tension testing machine, should be used. This enclosure should permit a frictionless

¹ This test method is under the jurisdiction of ASTM Committee D-9 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.01 on Electrical Insulating Varnishes, Powders, and Encapsulating Compounds.

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² *Annual Book of ASTM Standards*, Vol 10.01.

³ *Annual Book of ASTM Standards*, Vol 08.01.

⁴ Spring gages from John Chatillon and Sons, 83-30 Kew Gardens Road, Kew Gardens, NY 11415 or from Hunter Spring Co., One Spring Avenue, Hatfield, PA 19440, or its equivalent, have been found satisfactory for this purpose.

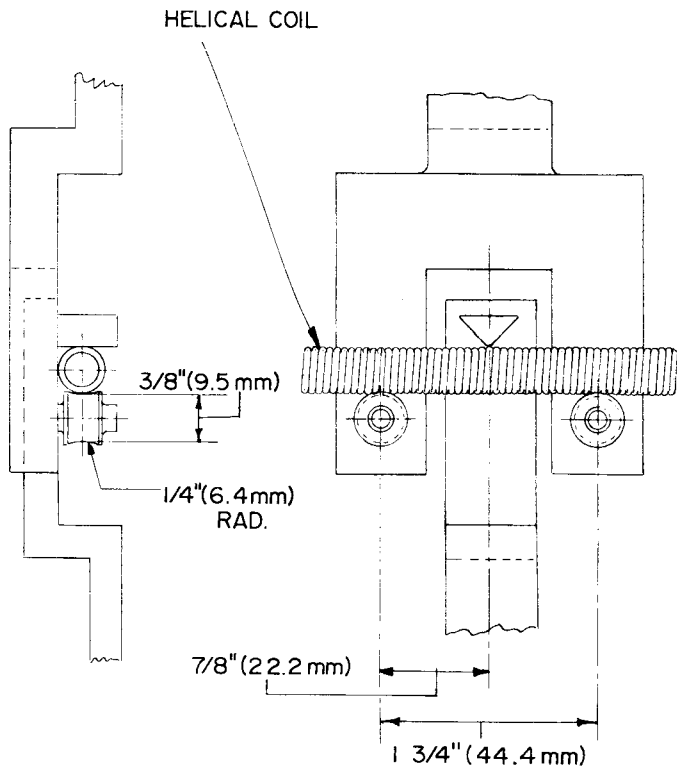


FIG. 1 Test Fixture for Bond Strength Test

connection between the test fixture and the instrument that measures the breaking force. The enclosure should have a suitable rack for holding six or more specimens. It should be heated or cooled by a separate source of uniformly circulating hot or cold air. The temperature control system should be capable of returning the test specimens and the chamber to the test temperature in less than 10 min. A thermostatic control, with the measuring thermocouple located within 25 mm (1.0 in.) of the center of the coil being tested, should be set to maintain the temperature of the chamber to within $\pm 2^{\circ}\text{C}$ of the desired temperature after the temperature has stabilized.

7. Safety Precautions

7.1 Varnish should not be used at temperatures above the flash point when inadequate ventilation and the possibility of flames or sparks exist. Varnish should be stored in sealed containers. The precautions shall also apply to the handling of the solvents and reagents used.

8. Test Specimens

8.1 The test specimen shall consist of approximately 75 mm (3 in.) long coils of No. 18 AWG wire, cut from a helix of convenient length which has been wound without space between turns on a 6 mm (0.25 in.) diameter mandrel. Bend the last loop on each end of the coil to approximately 90° to the coil to provide a means of support. Treat the coil with the varnish to be tested. The helical coil can be made from one of the following:

- 8.1.1 Bare aluminum wire,
- 8.1.2 Bare copper wire,
- 8.1.3 Film-coated magnet wire, or

8.1.4 Fiber-insulated magnet wire.

NOTE 1—A practical method of winding a tight helical coil is to guide the wire from the rotating reel between folds of a clean cloth onto the rotating mandrel using moderate hand tension. A trailing angle of 1 to 5° from a perpendicular to the mandrel should be maintained. When the wire is cut, the coil must be restrained to avoid rapid spring back.

8.2 The type of wire should be mutually agreed upon between the supplier and the user.

8.3 Prepare six or more specimens for each condition to be investigated.

8.4 Adjust the viscosity of the varnish to be tested, by trial, to produce a dry film build of 0.043 to 0.053 mm (0.0017 to 0.0021 in.) on a double coated aluminum panel coated in accordance with Test Methods D 115.

8.5 Coils made from bare wire shall be immersed in a solvent of 50 % toluene and 50 % denatured alcohol by weight for 30 min, removed and dried for 15 min at 100°C before being treated with varnish. Coils made from insulated wire should not be cleaned before being treated with varnish.

8.6 Attach several coils to a rack and immerse vertically in the varnish until bubbling stops. Withdraw them at 100 ± 5 mm/min (4 ± 0.2 in./min) and allow them to drain 10 to 30 min at the Standard Laboratory Atmosphere in accordance with Practice D 618. Place the coils in an oven in the same position as dipped at the temperature and for the time specified by the manufacturer. Reverse dip the coils, following the above procedure.

9. Procedure

9.1 *Rate of Loading*—Adjust the testing machine to a crosshead speed of 50 mm/min (2 in./min).

9.1.1 Position the coils in the test fixture with the center of the coils below the V-block. Each coil should be broken only once.

9.2 *Number of Specimens*—Test a minimum of five specimens for each condition. One of the original six specimens may be used for adjusting the testing machine.

9.3 *Selection of Test Range*—Select the proper test range which must correspond to the specified rate of loading. The proper test range is the one where the anticipated bond strength will be reached in the middle or upper portion of the test range, whenever possible. For testers with chart recorders it is essential that the test range be selected in such a manner that the event time is greater than the response time of the recorder.

9.4 *Tests at Other than Room Temperature:*

9.4.1 Adjust the temperature control until the temperature of a representative specimen in test position becomes constant within $\pm 2^{\circ}\text{C}$ at the specified test temperature, as indicated by a thermocouple located as prescribed in 6.3.

9.4.2 Break each specimen in the enclosure after temperature has been stabilized for 5 ± 1 min. A set of specimens may be placed in the oven at one time, then broken successively while the temperature of the enclosure remains constant, or, alternatively, each specimen may be preheated and broken individually.

10. Report

10.1 Report the following information:

- 10.1.1 Description of varnish,

- 10.1.2 Identification of wire used,
- 10.1.3 Cure time and temperature for each coat used to prepare the coils, and
- 10.1.4 The individual values in newtons (pounds-force) of bond strength and their averages at each test condition.

11. Precision and Bias

11.1 *Precision*—Data from an interlaboratory study of this test method, are as follows:⁵

⁵ Supporting data are available from ASTM Headquarters. Request Research Report RR: D-9-1010.

11.2 *Bias*—The bias of this test method is determined by the time of testing, the machine, and the test range used.

Combined data from all six laboratories except No. 3.

Mean = 228.2 N (51.3 lbf)

Standard deviation = 21.84 N (± 4.91 lbf)

95 % Confidence level = 42.79 N (± 9.62 lbf)

Combined data from all six laboratories

Mean = 220.6 N (49.6 lbf)

Standard deviation = 41.99 N (± 6.96 lbf)

95 % Confidence level = 82.25 N (± 13.64 lbf)

12. Keywords

12.1 bond strength; helical coil; varnish

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